

HISTORICAL BUILDING ENCLOSURE PERFORMANCE THROUGH THE LENS OF FORENSIC INVESTIGATIONS

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PART II

This article is an abridged adaptation of a white paper titled “Understanding Building Skins Through Failures: Trends in Failure Mechanisms and Their Costs,” originally presented at the 2018 Advanced Building Skins conference (<https://abs.green/home>).

INTRODUCTION

When a building enclosure system is designed, it is expected to perform as intended throughout its anticipated service life. However, when designs are implemented in construction, changes and compromises are often made that affect the actual longevity of the systems. In a previously published article in the July 2019 issue of *IIBEC Interface*, we investigated the apparent changes in the longevity of building enclosure systems as a whole throughout the past decades, and found that the average longevity of building enclosure systems in our sample population has generally decreased in recent decades, apart from a slight improvement in the 2000s. The data also showed us the changes in the most common modes of failure and the cyclic interaction among design, manufacture, and installation. But how do these broad-stroke trends relate to what we observe in individual building enclosure systems on a day-to-day basis? And within the general category of “building enclosure systems,” do different systems perform differently in response to changes in the industry? In this follow-up study, we examine the underlying systems in our data set to find out how they respond differently, and whether certain types of systems are more resilient to the trends uncovered in our previous study.

SAMPLE POPULATION AND METHODOLOGY

The sample population includes 130 building enclosure system failures in the Pacific Northwest that were analyzed in our previous study, further broken down into vertical and horizontal building enclosure systems. Vertical building enclosure systems include wall and glazing systems. We investigated failures in stucco, exterior insulation and finish systems (EIFS), lap siding, and windows in punched openings. Systems that were not as frequently investigated are grouped into the “other” category. These include structural insulated panels, metal panel siding, and exposed concrete walls. Horizontal building enclosure systems include low-slope roofs, nonexposed waterproofing, and waterproofing exposed

to pedestrian traffic (decks). Steep-slope roof systems are not included in this study.

By virtue of being a forensic consulting firm, data collected from our investigation projects are limited to systems that have reportedly failed. Successful installations are not included in our sample population. This is consistent with the goal of our study, which is to understand trends in failed systems. The results and percentages presented here therefore represent characteristics of failed systems and not the general population of all building enclosure installations. *Figures 1 and 2* illustrate the composition of our sample population.

As in our previous study, failed systems are defined herein as systems that are not performing their intended function (for example, permitting water infiltration

Vertical Systems Investigated

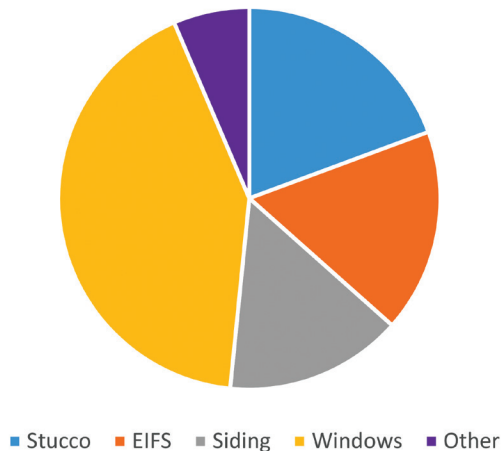


Figure 1 – Types of vertical building enclosure systems included in this study.

Horizontal Systems Investigated

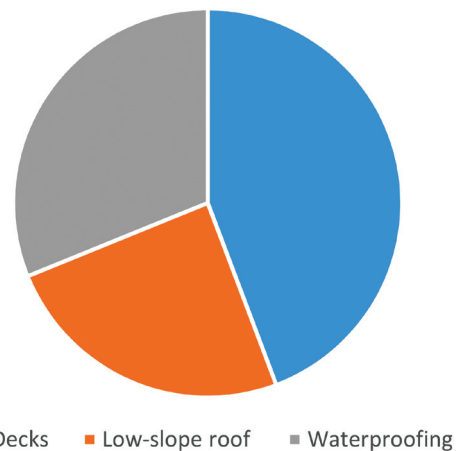


Figure 2 – Types of horizontal building enclosure systems included in this study.

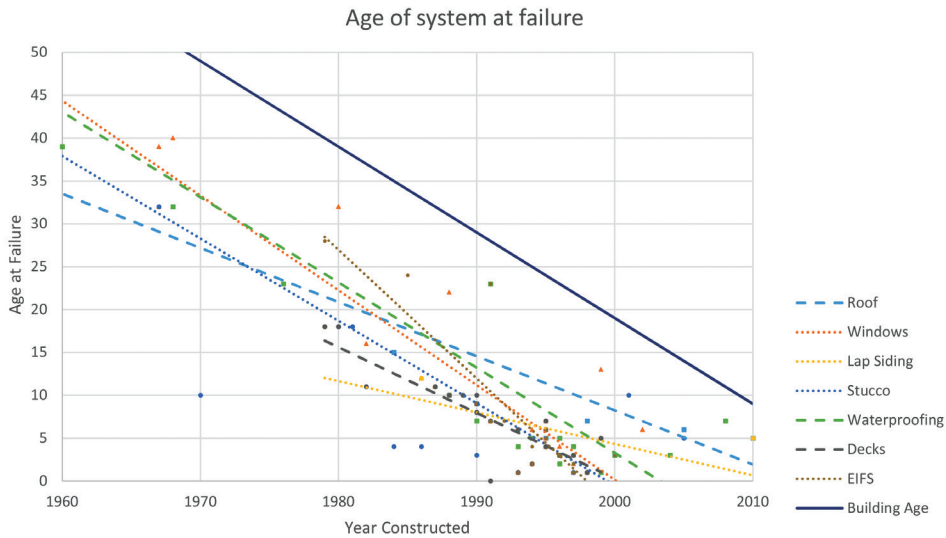


Figure 3 – Historical performance of building enclosure systems.

or air leakage), or systems that have deteriorated before reaching their design service life. A two-step process is inherent in identifying failures in our data set. First, failures have to be self-reported by building owners. Some indication of either non-performance or physical damage was noted by the building owner, tenant, or maintenance staff, triggering our investigation. Through forensic investigations, we then determined the cause of such failures. In our study, systems that were non-performing due to lack of maintenance or normal aging were not classified as failures. Isolated issues and items covered by a manufacturer’s warranty were also not included. Our sample population included only projects that were non-performing and required either systemic modifications or complete replacement before reaching either the published or industry average expected service life of the specific system investigated. To offer a point of comparison with our previous study, we focused on examining the age of each system at failure and the comparative trend of increasing or decreasing system longevity.

FINDINGS

Comparative Longevity of Building Enclosure Systems

The age of building enclosure systems at failure was plotted against their year of construction, shown in Figure 3. We noticed again a generally decreasing trend in system longevity. Windows and protected waterproofing are among the systems whose performances are most steeply in decline. The trend lines for lap siding and low-slope roof systems appear to have the most moderate slope.

We recognized that for younger buildings that have not had an opportunity to go through the full design life cycle, our data would inevitably be skewed to capture only systems that were failing “sooner” than those installed on older buildings. To address this, the data were normalized to show the relative age of each system at failure as a percentage of the building’s age. Trend lines were then fitted with cubic polynomial functions to reveal nuances in the general trend. We expected there would be a general downward skew to the trends revealed, but any upward trend would be worthy of investigation. The relative slopes of these trends were also examined. Major developments in the building enclosure industry in the past five decades were included as reference points in the graph (Figure 4). These include the oil embargo in the 1970s, the development of the Energy Code, the implementation of

the Washington State Condominium Act (Condo Act), and the popularization of rainscreen cladding systems and air barriers in building enclosure design in the Pacific Northwest.

We noted that within the general trend of declining system longevity, there are indications of reversal of that trend for most systems beginning in the mid-1990s to early 2000s. Most notably, EIFS longevity was in the steepest decline in the 1980s, but they have also shown one of the quickest reversals into the 2000s. The performance of vertical wall systems—lap siding, stucco, and EIFS—appears to be very much affected by the increased use of rainscreen systems in the late 1990s. Horizontal systems exhibit more gradual trends that relate to differing historical events. Performance of roofs, for example, appears to have responded very gradually to the development of the energy code in the 1970s and not much to other historic events. Decks, on the other hand, responded well to the energy code, but then experienced a dip in performance through the 1980s and 1990s before rallying again, along with vertical building enclosure systems, following the popularization of rainscreen systems. Waterproofing and window systems both appear to be unaffected by historic developments in the industry.

Average Longevity of Building Enclosure Systems

Next, we examined the difference between the actual observed service life of various building enclosure systems in the past three decades. We grouped each system into decades by their year of construction and looked at the average life of these systems

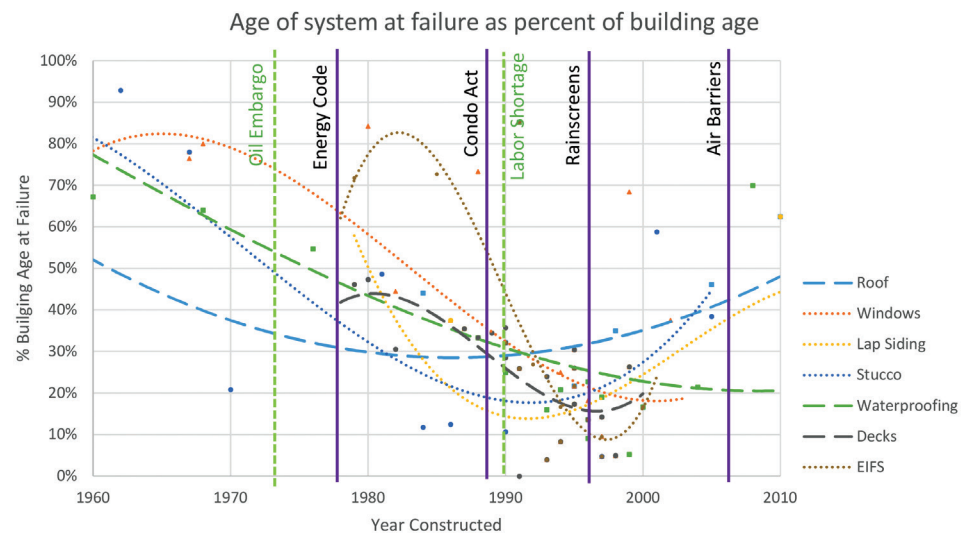


Figure 4 – Historical performance of building enclosure systems, normalized to building age.

within each decade to capture the change in performance we noted between the 1990s and 2000s. The general trends in horizontal and vertical system longevity are shown in *Figures 5 and 6*, respectively.

The most striking observation from *Figures 5 and 6* is that the average system age at failure did not increase in the 2000s for horizontal building enclosure systems as it did for vertical building enclosure systems. The figures also show that systems constructed in the 1980s generally lasted longer than systems constructed in the 1990s and 2000s. EIFS, in particular, reached an average of almost 25 years in service before failures were reported.

DISCUSSION

Factors Affecting Time in Service Before Reported Failure

One of the key goals in sustainable building design is to design buildings with systems that are adaptable and can stay in service for a long time. An assumption is often made that as time progresses, our building enclosure systems are designed and constructed better to last longer. If this is the case in practice, we would expect to see convergence between the building enclosure system age at failure and the building age—particularly in more recent years. For example, we would expect the system age trend line for a lap siding system to converge close to 100% in *Figure 4* for younger buildings built after 2010, as lap siding systems are not expected to fail so soon after construction. But this is not the case. We see in *Figure 6* that the average system age at failure for lap siding in the 2000s is seven years, down from close to 20 years in the 1980s. This seems to be the case in varying degrees for all of the systems in our sample population.

Many factors may account for this difference—not the least of which is the potential bias in our sample population. Without access to an exhaustive survey of all buildings in the Pacific Northwest, we are limited to collecting data only when problems are reported. The difference in reported age of failure depends not only on the performance of the building enclosure system, but also on the failure being noticed and reported. The observed shortening of time between construction and reported failure may very well be due to owners being more aware and reporting issues earlier. Another explanation could be that in recent decades, owners have become less inclined to self-perform

repairs before seeking professional advice.

Potential changes in owner behavior does not, however, explain the apparent increase in system longevity from the 1990s to the 2000s. Stucco, lap siding, and window systems have all enjoyed an increase in system life in the 2000s, despite the continued decrease of longevity in the other systems. Failures in window systems are arguably one of the easiest issues for building owners to notice. It is likely in this case that the combination of the Condo Act, which requires the submittal of stamped building enclosure

design documents during permitting and inspection of building enclosure components during construction, and the popularization of rainscreen designs did have a positive impact on these cladding systems.

One finding that was surprising was the continued trend of decreased longevity in EIFS. Most modern EIFS are designed as rainscreen systems rather than the barrier systems that were heavily litigated in the 1980s and 1990s. This new approach is intended to address the shortcomings of earlier EIFS designs and deliver better

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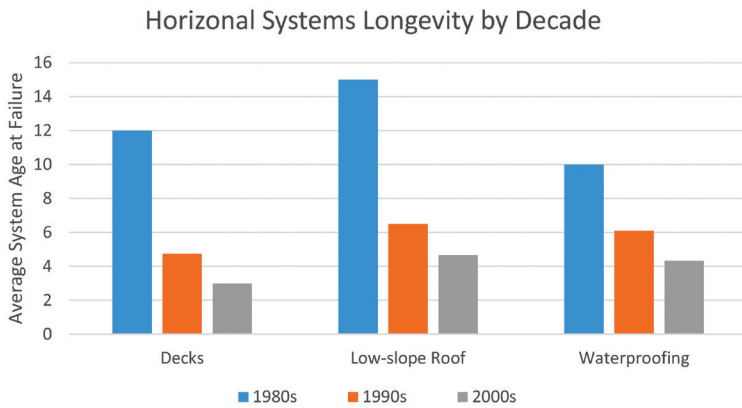


Figure 5 – Horizontal building enclosure system performance by decade.

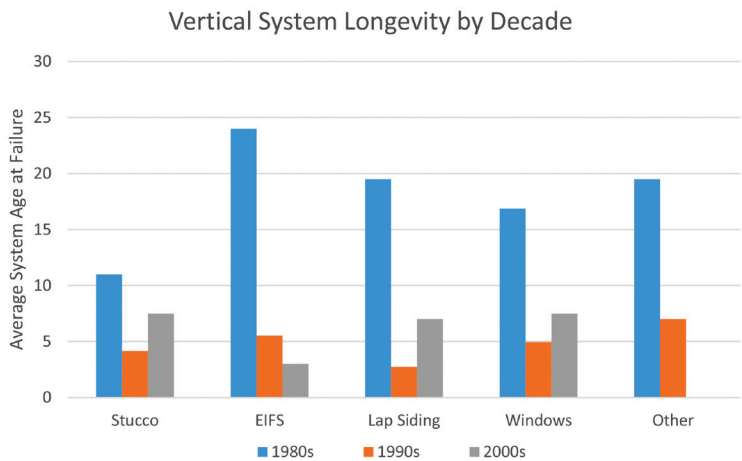


Figure 6 – Vertical building enclosure system performance by decade.

system performance. Yet we see in our study that the average age of EIFS at reported failure in the 2000s is less than it was in the 1980s and 1990s. This observation may be related to the limitations of this study. By nature of responding as forensic experts, our data can only capture systems that are not performing. Even if the majority of modern EIFS installed in the Pacific Northwest are successful, our data would still capture the minority of failed systems. Additionally, the litigious history of EIFS may have also created owner bias where sophisticated building owners are more sensitive to non-performance and report issues with EIFS sooner and more often.

Difference in Building Enclosure Systems' Responses to Industry Changes

There is much variation among building enclosure systems, both in terms of observed longevity and their responses to overall industry changes, as illustrated in Figures 3 and 4. For example, the popularization of rainscreen designs affected vertical building enclosure systems significantly more than horizontal building enclosure systems.

sub-industry, the availability of trained labor to construct modified details, and the relative complexity of materials and assemblies of each of these systems. These observations highlight the challenge in our study to draw general observations from systems that are widely varied and affected by sometimes independent events. We attempted to include milestone events in Figure 4 that may impact the construction industry as a whole. However, individual systems are also affected by system-specific changes in codes, design, and construction practices. These system-specific timelines are unfortunately beyond the scope of this study. It would be valuable to the industry for further analysis to be done for each system with these system-specific timelines so that we can better understand the nuances of how specific changes affect individual systems.

While this study is not designed to reveal definitively which event or industry developments directly impact changes in building enclosure system performance, it does show which systems are resilient to those changes. Roofing and protected waterproofing systems appear to be only

marginally responsive to industry milestone events. We see in Figure 4 that the trend lines for system longevity for roofing and protected waterproofing are remarkably smooth through the oil embargo, labor shortages, the development of energy codes, the Condo Act, and the general increase in awareness of the need for air barriers. This is a good example of the importance of studying system-specific timelines.

Low-slope roofing systems underwent a number of significant changes in the 1970s and 1980s where new materials and systems were introduced, which improved general performance of low-slope roofing systems installed after that time. It is probable that these changes were more impactful to the roofing industry than the Condo Act and the increased use of rainscreen systems alluded to in Figure 4. They were also likely responsible for the apparent resilience of low-slope roofing systems to the impact of labor shortages in the 1990s.

Being resilient to industry changes such as labor shortages can be an advantage. But this resiliency is also a disadvantage because it suggests that it may be more difficult to positively impact the performance of these systems with non-system-specific changes in codes and standards.

On the other hand, stucco and lap siding have trend reversals that most closely correlate to the implementation of the Condo Act. Their system longevity increased quickly in the 1990s and 2000s. This is perhaps in part due to the fact that stucco and lap siding are two very popular cladding choices for condominiums in the Pacific Northwest. EIFS also responded positively and quickly in the mid-1990s to the rainscreen design approach, following a steep decline that began in the mid-1980s. These findings suggest that vertical cladding systems may be generally more receptive to industry-wide efforts to improve building enclosure performance but are also more susceptible to negative events in the industry.


These differences can be attributed to many factors, including how new knowledge is disseminated within each

CONCLUSION AND RECOMMENDATIONS

We began this study seeking to answer the question of whether certain building enclosure systems are more resilient to the general trend we observed in our previous, more broad-strokes study of what we've seen in building enclosure systems as a whole. The answer appears to be a definitive yes. In addition, we have learned that certain systems were less likely than others

to be impacted—either positively or negatively—by changes in codes and standards and by industry milestones. Even changes in legislation intended to comprehensively improve building enclosure performance across the board, such as the Condo Act, did not improve performance evenly across the spectrum of systems we’ve studied. This study showed that while it is invaluable to focus on individual systems to solve system-specific design and construction issues, it is also helpful to perform global comparisons among different systems. This global comparison allowed us to understand the relative impact of industry-wide changes on different systems, which can potentially help us focus future legislative efforts to achieve more broad-spectrum results.

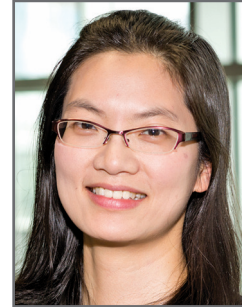
Constraints of time and resources have limited this study to a small population of buildings in the Pacific Northwest. However, this framework for forensic data-mining analysis could be applied to larger data sets and to each building enclosure system category investigated here. Further study using data from multiple firms in different areas of North America could allow for comparison of the impact of legislation on different

systems in various climates. Further investigation of roofing and protected waterproofing systems should also be performed to determine the reasons for their resiliency to industry events that have apparently negatively affected performance of other systems, and whether those characteristics can be developed in other systems. 

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